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Department of
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**Natural
Resources
Conservation
Service**

Agricultural
Waste Management
Field Handbook

Chapter 13 Operation, Maintenance, and Safety

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651.1300 Introduction

The purpose of an Agricultural Waste Management System (AWMS) is to control and use by-products of agricultural production in a manner that sustains or enhances the quality of air, water, soil, plant, and animal resources. Important to the success in achieving this purpose is adequate design and construction of the AWMS. At least as important to a system's success are its proper operation and maintenance (O&M). Safety is always coupled with proper O&M as an essential and integral part.

This chapter describes actions that would be taken by the operator of an AWMS or choices that would be made by the decisionmaker. It recognizes that the decisionmaker and the operator for an AWMS may not be the same person. For example, on an absentee owner's farm the decisionmaker and the operator are most likely different people. However, for the purpose of this chapter, reference to the decisionmaker implies the operator when appropriate to the context. The operation and maintenance described in this handbook is not all inclusive, but addresses the most common components.

Two prerequisites are necessary for proper O&M. First, the decisionmaker must have been involved throughout the decisionmaking process in planning the AWMS. This is essential if the decisionmaker is to accept full ownership of what is planned. Second, the decisionmaker must have a complete understanding of the system's O&M requirements. The AWMS plan is an essential tool for conveying these requirements to the decisionmaker. An AWMS plan is prepared as an integral part of and in concert with conservation plans. The purpose of this chapter is to discuss general operation, maintenance, and safety requirements for an AWMS.

651.1301 Operation

Operation of an AWMS includes the administration, management, and performance of nonmaintenance actions needed to keep the system safe and functioning as planned. The operation actions required depend on such factors as the type of enterprise, the components of the system, and the level of management. Because of this, the operational requirements for each AWMS must be system-specific. Following is a general description of the operational requirements for each function of an AWMS.

(a) Production function operation

The majority of the operational actions required for the production function are managerial. Examples of operation actions could include management of the amount of bedding and washwater used. The AWMS plan should document the production rate assumed in the design of the system and give a method for determining the actual rate. An important reason for doing this is to assure that the actual rate does not exceed that assumed in the design of the system. Repercussions can occur if the design rate is exceeded. For example, a storage facility of an AWMS could fill up more quickly than anticipated, requiring that the facility be emptied earlier than intended. A response is needed where a production rate exceeds design assumptions. For a dairy operation, the response might be reducing the amount of daily washwater used, excluding clean water entering the system, or enlarging the storage facility.

(b) Collection function operation

The collection function involves the initial capture and gathering of waste from the point of origin or deposition to a collection point. The managerial aspects of this function involve frequency and timing, which should be described in the AWMS plan. Frequency of collection is dependent on the type of operation. For a feedlot, the frequency of collection might be only once a year. On the other hand, a dairy with a flush system might collect waste several times a day.

Timing of collection can be an important consideration. For a feedlot without a storage facility, the timing should coincide with when the waste can be utilized. Timing for a poultry broiler operation may be most appropriate between production cycles when the facility is empty of birds.

(c) Storage function operation

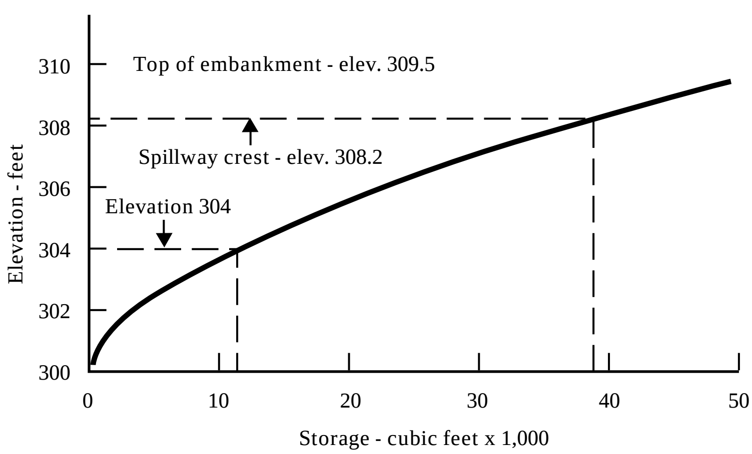
Storage function components include waste storage ponds and structures. Storage structures include tanks and stacking facilities. Monitoring storage levels in relationship to the storage period is of prime importance in the operation of storage components.

The AWMS plan should give target storage levels by date throughout the storage period. To assure that the facilities do not fill prematurely, these levels should not be exceeded. An excellent way to present this in the AWMS plan is to equip an impoundment type storage facility with a staff gauge so that target gauge readings versus dates are given. A stage-storage curve (fig. 13–1) can also assist the decisionmaker in monitoring the storage's filling. The stage-storage curve relates the pond's water surface at any elevation to the pond's storage at that elevation. For example, if the waste storage pond for figure 13–1 was measured as having a water surface elevation of 304 feet, it can be determined using the stage-storage curve that the pond contains 12,500 cubic feet of wastewater at that elevation. This storage can then be compared to anticipated storage if the pond had filled at the design filling rate.

To illustrate comparing actual versus design filling rate using the stage-storage curve, say the pond above is in its 50th day of the storage period, and the design filling rate is 200 cubic feet per day. Therefore, the target storage level for that day would be: 200 cubic feet per day times 50 days, or 10,000 cubic feet plus the depth of precipitation less evaporation assumed to occur during this 50-day period.

Using the stage-storage curve, it can be determined that at a storage of 10,000 cubic feet the water surface elevation in the pond would be 303.4. Add the assumed depth of precipitation less evaporation assumed for this 50-day period to this elevation.

Figure 13–1 Stage-storage curve



For this example, if the precipitation less evaporation was assumed in design to be 0.6 feet, the target filling elevation for the 50th day would be 303.4 + 0.6 = 304.0, which would indicate actual filling is at the assumed design rate. However, actual precipitation amounts may vary from that assumed in design. For this reason, actual precipitation less evaporation should also be evaluated. For example, if the actual precipitation is less than that assumed, it would mean the pond above is filling at a rate in excess of the 200 cubic feet per day. On the other hand, if the actual precipitation less evaporation is more, the pond is filling at a rate less than the 200 cubic feet per day.

Keeping a record of the waste accumulation throughout the storage period should be recommended. A record of precipitation and evaporation amounts may also be important in determining the source of filling.

Storage components are generally operated so they are empty at the beginning of the storage period and are filled to or below capacity at the end. The management of storage components may need to be coordinated with the management of the production function if the rate of filling exceeds that assumed in design. Uncovered impoundment storage components are subject to storm events that prematurely fill them. The AWMS plan should describe a procedure for emptying these facilities to the extent necessary in an environmentally safe manner to provide the capacity needed for future storms.

The design of liquid storage components may require a storage volume reserve for residual solids after the liquids have been removed. The amount reserved for this purpose depends on such things as the agitation before pumping and the care taken in pumping.

(d) Treatment function operation

Treatment components include waste treatment lagoons, composting, oxidation ditches, solid/liquid separation, and drying/dewatering. The treatment function reduces the polluting potential of the waste and facilitates further management of the waste. Proper operation of this function is essential if the desired treatment is to be achieved.

(1) Waste treatment lagoons

Proper operation of waste treatment lagoons includes maintaining proper liquid levels and assuring that the maximum loading rates are not exceeded. Lagoons are designed for an assumed loading rate. The AWMS plan should document the maximum loading rate and suggest that it be monitored to assure that it is not exceeded. This can be done by comparing the sources and amounts of waste entering the lagoon to what was considered in design, such as number of animals.

Laboratory testing may be required if loading becomes a serious question. If the design loading rate is exceeded, the lagoon may not treat the waste as needed and undesirable and offensive odors may result. The rate of filling is important as well. If the rate of filling exceeds the design rate, the storage period is reduced and the lagoon must be pumped more frequently. See section 651.1301(c). The AWMS plan should describe a procedure for emptying part of the lagoon contents following a storm event that fills the lagoon prematurely to near its capacity to provide storage for future storms.

The AWMS plan must emphasize the need to maintain the liquid level in anaerobic lagoons at or above the minimum design volume (fig. 13–2). The proper pH must also be maintained if the desired treatment is to be achieved. As such, the pH should be measured periodically. The minimum acceptable pH is about 6.5. If pH falls below 6.5, a pound of hydrated lime or lye should be added per 1,000 square feet of lagoon surface daily until the pH reaches 7.0.

Aerobic lagoons require a design surface area and a depth within the range of 2 to 5 feet to effectively treat waste. This information must be provided in the AWMS plan. Mechanically aerated lagoons require that a minimum design volume be maintained and the designed amount of aeration be provided for effective treatment and odor reduction. The plan should recommend that these operational aspects be carefully monitored.

(2) Composting facilities

Composting requires careful management to effectively treat waste. It relies on a proper blend of ingredients, called the recipe, to achieve the microbial activity necessary to stabilize reactive constituents and to attain the temperature necessary to destroy disease-causing organisms. For this reason, the AWMS plan should address careful monitoring of internal temperatures in the compost pile. The plan should give the recipe and recommendations for its adjustment if the temperature levels are either too low or too high. Caution should be given to the potential for spontaneous combustion. The plan must also address mixing requirements. See chapter 10 for a complete discussion of the management responses necessary for effective composting.

(3) Solid/liquid separation

Solid/liquid separation facilities include settling basins and a variety of stationary and mechanical screening devices. Maximum and minimum allowable flow rates are critical for these type facilities and need to be documented in the AWMS plan. If the flow rate exceeds the rate assumed in design, the residence time in settling basins may not be adequate for efficient settling. If it exceeds the design capacity of a screening device, its efficiency will diminish. Generally, the screen manufacturer's information provides data on minimum and maximum flow rates. However, the decisionmaker may need to fine tune the flow rate to fit the consistency of waste produced.

The frequency of cleaning out settling basins needs to be established by the design and documented in the AWMS plan. Solids sometimes adhere to screening devices and, if allowed to dry, can clog the screen. Rinsing the screen following use should be emphasized in the AWMS plan as a way to help avoid this problem.

(4) Oxidation ditches

Oxidation ditches require a high level of management to effectively treat the waste in a safe manner. Careful attention must be given to assure that pumps and other equipment are operating properly and that the ditch is not overloaded. Velocities must be maintained that do not permit solids to settle and accumulate. Input from the designer is essential in developing the operational requirements for oxidation ditches.

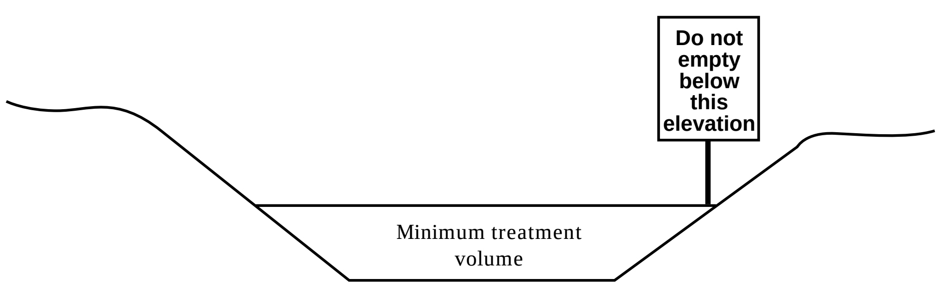
(e) Transfer function operation

Transfer function components include reception pits, pipelines, picket dams, pumps, and other equipment, such as tank wagons, agitators, chopper-agitation pumps, and elevators. A surveillance type inspection should be recommended to assure that the components are functioning properly.

A clean water flush following use of pipelines, tank wagons, and conveyors is helpful in minimizing the build up of sludge. Methods for unplugging pipelines should be described. Draining of pipelines or other protective freeze protection measures should be addressed.

Struvite, a phosphate mineral that can form a hard-scale deposit in pipelines and other similar waste transfer components, is a potential problem in an AWMS that utilizes recycled lagoon or waste storage pond effluent for flushing. Occasional clean water

Figure 13–2 Maintenance of minimum treatment volume



flushes of the transfer component or addition of struvite formation inhibitors to the wastewater may be effective in reducing struvite buildup. If a struvite buildup occurs, the system may need to be cleaned with an acid solution.

Proper agitation prior to transfer needs to be described in the AWMS plan. Agitation should be continued long enough so that the solids in the waste, including those in corners and recesses, are moved into suspension. The plan should address the spacing and duration of agitation. It should also give any precautions needed during agitation to prevent damage to pond liners. The consequences of inadequate agitation can be solids buildup, which can lead to difficult problems.

(f) Utilization function operation

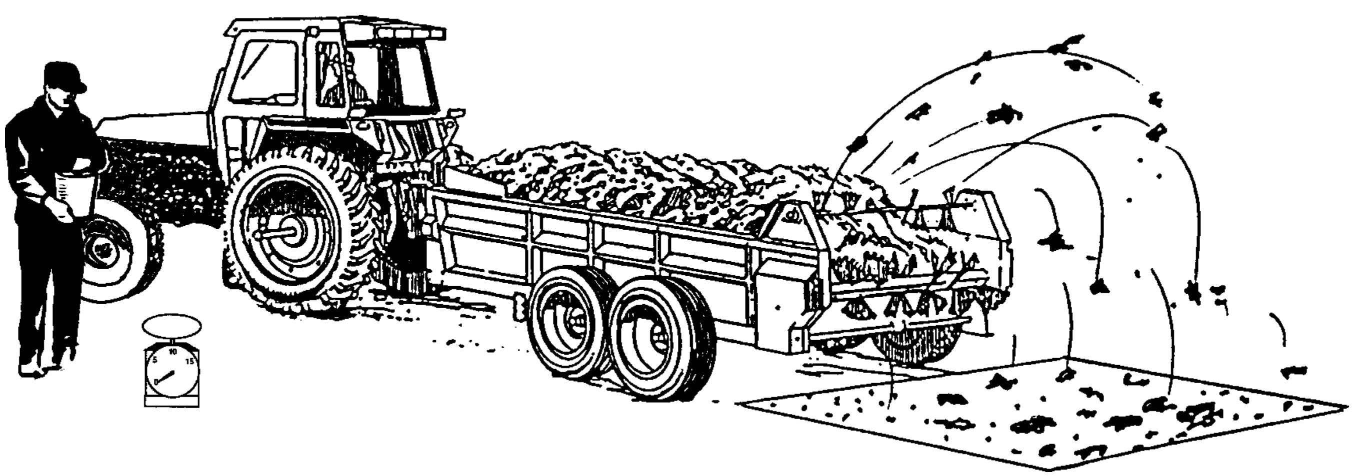
Utilization is a function in an AWMS for the purpose of taking advantage of the beneficial properties of agricultural wastes, such as its nutrient content. Components of utilization are land application of nutrients and biogas generation. Land application is the most prevalently used method.

The AWMS plan should establish the amount, method, placement, and timing of land application of agricultural wastes. The timing required should consider climate and stage of crop growth to maximize crop uptake and minimize environmental impact. Timing should also consider the potential for premature germination of planted crops if the waste is applied too early. Testing the waste and the soil for nutrient content must be recommended as good practice for use in determining the actual rates of application. See appendix 13A for more information on manure testing.

For liquid waste applied with an irrigation system, the plan should give sprinkler numbers, size and types of sprinklers, length of setting, and flow rates of waste and dilution water, if any. For slurry or solid wastes, the plan should indicate the necessity of calibrating spreading equipment to assure the desired rate of application is achieved (fig. 13–3). Appendix 13A also describes several methods of manure spreader calibration.

Utilization involving biogas/methane production and recovery requires a high level of management to be successful. Complicating the operation of a digester is coordinating use of gas once it is produced. Since compression and storage of biogas is not practical, its use must generally match the energy production. The designer of the biogas system must be involved in developing the specific operational requirements.

Figure 13–3 Manure spreader calibration



Methane production and recovery system options include the covered anaerobic lagoon, complete mix digester, and plug flow digester. Because each operates at a constant level and does not provide for waste storage, they must be operated in conjunction with a storage facility of some type. Operation of biogas components is dependent upon proper loading of waste in terms of volatile solids, total solids, and waste volume. As such, their loading must be carefully monitored. Some manure requires treatment, such as solid/liquid separation and dilution, before it enters a lagoon or digester. The amount of gas produced is a good indication of proper loading. If gas production falls off, the loading should be checked.

(1) Covered anaerobic lagoon

Operation of a covered lagoon for biogas production is much like that of a lagoon not associated with biogas production. The exceptions are that it is operated to have a constant liquid level, loaded at a higher rate, and has a minimum hydraulic retention time.

The inlet and outlet of the covered lagoon must remain free-flowing to maintain the required liquid level. The lagoon cover requires special attention to assure that methane produced is captured and directed to where it will be used. The cover should be periodically inspected for accumulation of excessive rainwater, tearing, wear holes, and proper tensioning. Excessive rainwater should be removed in the manner prescribed by the designer, usually by pumping or draining it into the lagoon or storage facility.

(2) Complete mix and plug flow digesters

These digesters require a constant temperature within a narrow range of variation to produce an optimum amount of biogas. Temperature is maintained by a heating system. The digester operating temperature must be monitored and kept within the temperature range specified by the designer. If the heating system is not functioning properly, waste should be routed around the digester to the storage facility. Both digesters have a cover of some kind. Like the lagoon cover, they must be periodically inspected to assure they are in good condition and are directing the gas to the exit point.

Effluent from anaerobic digesters has essentially the same amount of nutrients as the influent. As such, the O&M plan must address use of the effluent for land application.

651.1302 Maintenance

Maintenance of an AWMS includes actions that are taken to prevent deterioration of the system components, to repair damage, or to replace parts. Maintenance includes routine and recurring actions. The purpose of maintenance is to assure proper functioning and to extend the service life of AWMS components and equipment.

The two types of maintenance required by an AWMS are preventive and reactive. Preventive maintenance involves performing regularly scheduled procedures, such as lubricating equipment and mowing grass. Reactive maintenance involves performing repairs or rehabilitation of system components and equipment when they have deteriorated or cease to function properly. Examples of reactive maintenance include repair of a leak in a waste storage structure and replacement of a badly corroded piece of pipeline.

Essential to reactive maintenance is the discovery of items requiring attention before there is a serious consequence. Timely discovery can best be accomplished by regularly scheduled inspection of the AWMS components and equipment. The general maintenance and inspection requirements that should be considered for inclusion in the AWMS plan for each function of an AWMS are described in this section.

Proper maintenance of equipment used in an AWMS is essential for continuous operation. A thorough inventory of each function and its related equipment is recommended as a way to organize what must be maintained. The AWMS plan should recommend actions that will assist in the maintenance of equipment. An action to include would be collecting and filing information on equipment, such as name plate data, shop manuals, catalogs, drawings, and other manufacturer information. Other actions to recommend:

- Prepare checklists that give required maintenance and maintenance frequency.
- Keep a log book of the hours each piece of equipment is used to assist in determining when maintenance should be performed.
- Keep a replacement parts list indicating where the parts can be obtained.
- Keep frequently needed replacement parts on hand.

(a) Production function maintenance

(1) Roof gutters and downspouts

A good time to inspect roof gutters and downspouts is during storm events when leaks and plugged outlets can easily be discovered. Maintenance items would include cleaning debris from the gutters, unplugging outlets, repair of leaks, repair or replacement of damaged sections of gutters and downspouts, repair of gutter hangers and downspout straps, and repair of protective coatings.

(2) Diversions

Maintenance of diversions includes, as appropriate to the type of construction, mowing vegetation, eliminating weeds, repair of eroded sections, removal of debris and siltation deposits, and repair of concrete. Inspections should be made on a regularly scheduled basis and after major storm events.

(b) Collection function maintenance

Maintenance requirements for the collection function are primarily directed at mechanical equipment. Regularly scheduled lubrication and other preventive maintenance must be performed on electric motors, sprockets, and idle pulleys according to the manufacturer's recommendations.

Flush systems employ pumps, valves, and mechanical equipment involving gear boxes, stems, and guides. This type equipment also needs regularly scheduled preventive maintenance. Broken sprockets, idle pulleys, drive cables and rods, chains, and scraper blades must be repaired when they are seen to be damaged.

Tractors used in collection must be regularly maintained according to the manufacturer's recommendations. Equipment used in collection must be under constant surveillance to assure continuous and proper operation. Grates and covers on reception pits must be kept in place and in good condition.

(c) Storage function maintenance

(1) Waste storage ponds

Regularly scheduled inspections and timely maintenance are required for waste storage ponds because their failure can result in catastrophic consequences. The consequences of failure may affect public safety and environmental degradation. Inspections should focus on and result in the repair of leaks, slope failures, excessive embankment settlement, eroded banks, and burrowing animals.

Flow from toe and foundation drains should be inspected for quantity of flow changes and for discoloration. If flows from these drains suddenly increase, it could mean a leak has developed. If the flow is normally clear and suddenly becomes cloudy with silt, piping of the embankment could be suspected. Appurtenances, such as liners, concrete structures, pipelines, and spillways, need to be inspected and repaired if found to be deficient. Vegetative cover needs to be routinely maintained by mowing, and weeds and woody growth need to be eliminated. Safety features, such as fences, warning signs (fig. 13–4), tractor stop blocks, and rescue equipment, need careful maintenance.

Earthen waste storage ponds should be inspected carefully during and after they are emptied. Generally, these ponds are completely emptied over a short time. A consequence of this drawdown may be inside bank failures, especially where the pond is constructed in heavier soils or has an imported soil liner constructed

Figure 13–4 Waste storage pond warning sign

of heavier soils. Therefore, it should be recommended that the pond be carefully inspected during and immediately after emptying. Some pond features are best inspected when the pond is filling or is full. For example, inspection for toe drainage and foundation leaks is best done when the pond is filling or full.

(2) Waste storage structures—tanks

Inspection and maintenance of waste storage tanks depend on the type of tank and the material used in construction. However, regardless of the construction they should be inspected regularly for leaks and degradation. Concrete tanks should be inspected on a regularly scheduled basis for cracks and degradation of the concrete. Any sudden or unexpected drop or rise in the liquid level should be documented, the cause investigated, and the problem corrected.

Inspection or repair of waste storage tanks is a hazardous undertaking because it may involve entry into the tank where toxic, oxygen displacing, or explosive gases may be present. The safety section of this chapter gives a procedure for safe entry into confined spaces. Because of the caustic nature of wastes, a specialist in the repair of concrete should be consulted if cracks or degradation of concrete are observed.

An important consideration for below ground tanks is maintaining the water table below the elevations assumed in the design of the tank. Drains installed to control the water table must be inspected on a regular basis to assure that they are operating properly. If applicable, a caution should be included in the AWMS plan that liquid waste or water should not be allowed to pond on the ground surface surrounding the tank. This ponding can result in hydrostatic pressures that exceed the tank's design loadings, which can cause cracking or uplift.

A popular material for aboveground waste storage tanks is fused glass-coated steel. This material is virtually indestructible to the caustic action of the waste if the coating remains intact; however, deterioration of the steel may result if the coating is damaged. As such, it is important that the surface of these tanks be regularly inspected and repairs made. The area around bolts should be checked for loss of coating and rusting. Repairs should be made according to the manufacturer's recommendations.

Cathodic protection is required for some installations. When included, the cathodic protection system should be inspected to assure that it is functioning properly. The cathodic protection inspection requirements are dependent upon the type of system installed. The designer of the cathodic protection should be consulted on what to include in the O&M plan.

Steel tanks generally are not designed to withstand a load against the outside of the tank. Because of this, waste or other material should not be allowed to build up against the outside wall of the tank.

Careful attention needs to be given to the maintenance of safety features associated with waste storage tanks. These features include warning signs, grates and lids for openings, fences, barriers, and rescue equipment. Grates, lids, and gates should be secured in place when left unattended.

(3) Waste storage structures—Stacking facilities

Concrete and lumber are used in the construction of waste stacking facilities. Concrete should be inspected for cracks and premature degradation. If any problems are found with the concrete, appropriate repairs should be made.

Lumber should be inspected for damage either by natural deterioration or from man, animal, or weather event causes. Damaged lumber should be replaced. Roofs should be inspected regularly for leaks and damaged trusses, and repairs made promptly.

(d) Treatment function maintenance

(1) Waste treatment lagoons

The inspection and maintenance requirements for a waste treatment lagoon are about the same as those for a waste storage pond. One difference is that ponds generally are completely emptied, whereas lagoons retain a minimum storage pool. Maintenance of aerated lagoons would be complicated by the aeration equipment involved. The AWMS plan should indicate that the maintenance of the aeration equipment is to be according to the manufacturer's recommendations.

(2) Composting facilities

Composting facilities vary widely mainly because there are several methods of composting. However, many facilities use standard construction materials, such as concrete, concrete blocks, lumber, and steel.

Concrete should be inspected regularly for cracks and deterioration, and repaired as necessary. Lumber should be inspected for deterioration and physical damage, and replaced if found to be nonservicable. Protective coatings for steel structures should be inspected and repaired when damage is found. Manufactured composters should be maintained according to the manufacturer's instructions.

(3) Solid/liquid separation facilities

Settling basins are constructed of earth, concrete, or other material. Inspection and maintenance of these facilities are much the same as those for components constructed of similar material.

Screening devices are generally constructed using various kinds of steel. These devices should be inspected regularly for deterioration of protective coatings, and repaired as necessary. Many of these devices also involve the use of electric motors, pumps, and gears. These should be routinely maintained as recommended by the manufacturer.

(4) Oxidation ditches

The channel for oxidation ditches is generally constructed of concrete. The concrete should be inspected regularly for cracks and deterioration, and repairs made as needed. The rotor should be lubricated regularly and inspected for proper operation. Other equipment, such as pumps, agitators, and valves used in its operation, should be maintained as recommended by the manufacturer.

(e) Transfer function maintenance

Components and equipment for the transfer function of an AWMS vary widely. Manufactured transfer equipment, such as pumps, conveyors, and tank wagons, should be maintained according to the manufacturer's instructions. Pipelines should be inspected to assure that proper cover is maintained, vents are not plugged, valves are working properly, and inlet and outlet structures are in good condition.

(f) Utilization function maintenance

Waste utilization equipment includes solid manure spreaders, liquid manure spreaders, injection equipment, and irrigation equipment. The equipment should be maintained according to the manufacturer's recommendation.

If covered lagoons are used for biogas production, maintenance is similar to that needed for uncovered lagoons. The covered lagoons and other covered digesters need routine inspection of the covers or enclosures to check for tears or other opening that would allow gas to escape. Timely repairs must be made. The covered lagoon is generally designed for a constant level that is controlled by a pipe that discharges to either another lagoon or a waste storage pond. This pipe must be kept free of obstructions. Digestors accumulate sludge that must be periodically removed. Some digesters are heated, and use pumps to circulate heated water. These pumps must lubricated and impellers and seals repaired as necessary.

651.1303 Safety

Safety hazards are inherent to an agricultural waste management system. Some of these hazards lie hidden and await the unsuspecting. Others may be more obvious, but are just as formidable to the careless. For these reasons, attention to safety must always be given first consideration in the planning, design, construction, and operation of an AWMS.

Hazards associated with an AWMS can be minimized by incorporating safety features in the design and consequent construction of AWMS components. The AWMS plan needs to address operation and maintenance of these safety features. The safe operation requires that those involved in its operation be aware of the system's hazards, follow procedures of safe operation, and maintain its safety features. These procedures must be clearly defined in the AWMS plan.

Hazards associated with an AWMS are many and lurk in each of its functions. Because safety hazards of similar nature are not limited to one function, they will be described as those associated with gases, impoundments, and equipment operation.

Most states have rules and regulations for occupational safety and health in agricultural operations. The state occupational safety and health agency should be contacted to determine applicable regulations. The AWMS plan should be developed to be in accordance with these rules and regulations and the type of hazards that will be involved in the AWMS.

(a) Hazards from gases

A variety of gases can be generated in the operation of an AWMS. Some of these gases are toxic and can cause illness and even death at relatively low concentrations. Other gases are not toxic, but can displace oxygen and result in asphyxiation. What makes these gases especially insidious is that some are colorless and odorless, and defy detection except with specialized equipment. Colorless gases produced by an AWMS include carbon dioxide, ammonia, hydrogen sulfide, and methane. Numerous odorous gases are produced by an AWMS. These gases fall into the general classification of amines, amides, mercaptans, sulfides, and disulfides.

No direct tie between odors and safety problems has been found; however, odors can be a nuisance and cause complaints and even lawsuits. As such, they are an important consideration in the operation of an AWMS and need to be minimized. Chapter 8, Siting Agricultural Waste Management Systems, describes ways that odor problems can be minimized.

Gases can accumulate in any area of an AWMS where proper ventilation is not provided, such as animal housing and covered manure impoundments. Certain activities, such as agitation, can release gases that can cause problems if the facility is not properly ventilated. The major gases that may be produced by an AWMS and the consequences if these gases are encountered by humans and animals are described in the following paragraphs.

(1) Gases produced in an AWMS

Carbon dioxide (CO_2)—Carbon dioxide is a by-product of manure decomposition. Most of the gas bubbling up from storage and lagoons is CO_2. Carbon dioxide is not highly toxic in itself, but contributes to oxygen deficiency or asphyxiation. Concentrations above 10 percent (by volume) can cause a human to pant violently, and at increased levels are narcotic even if adequate oxygen is available. At 25 percent concentration, death occurs to humans after a few hours. Animals can tolerate up to a 7 to 9 percent CO_2 concentration, but with considerable discomfort. Concentrations above 10 percent may cause dizziness and even unconsciousness in animals.

Ammonia (NH_3)—Ammonia is released from fresh manure and anaerobic decomposition. Odors from as little as 0.0001 percent concentration can be detected and identified. Mixtures over 16 percent with air are explosive. Low concentrations, 0.0025 to 0.0030 percent, can irritate eyes and the respiratory tract of humans; higher levels can cause suffocation. Ammonia is an irritant to animals at concentrations up to 0.02 percent inducing sneezing, salivation, and appetite loss. Above 0.005 percent, eye inflammation develops in chickens. Prolonged exposure may increase respiratory diseases and pneumonia.

Hydrogen sulfide (H_2S)—Hydrogen sulfide is produced by anaerobic decomposition of organic wastes. It smells like rotten eggs at low concentrations, but cannot be detected at higher concentrations because it overpowers the sense of smell. High concentrations can be released by agitation and pumping. H_2S is the most toxic gas associated with manure storage, being both an irritant and asphyxiant. It is also flammable. Low concentrations severely irritate the eyes and respiratory tract of humans within an hour. Concentrations of 0.1 percent cause immediate unconsciousness and death through respiratory paralysis. Animals living continuously in facilities where the level of H_2S is 0.002 percent develop nervousness, appetite loss, and fear of light. Concentrations at 0.005 to 0.02 percent can cause vomiting, nausea, and diarrhea.

Methane (CH_4)—Methane is an odorless gas produced by anaerobic decomposition of organic wastes. It is not normally considered a toxic gas; however, it is highly explosive when mixed with air in concentrations as low as 5 percent. Lighter than air, methane tends to accumulate near the top of stagnant corners of buildings or covered manure impoundments. Accumulations of methane can be asphyxiating to both humans and animals; however, explosions are a more serious concern.

Carbon monoxide (CO)—Carbon monoxide gases in an AWMS result from operation of internal combustion engines and from gas, oil, and coal heaters rather than the decomposition of organic wastes. CO is mentioned because it is generated by equipment used in the operation of an AWMS. It is a colorless, odorless, toxic gas that can cause drowsiness at low concentrations and death at high concentrations.

(2) Gas hazard situation categories

Gases generated by an AWMS can be lethal if ventilation systems break down, during agitation of waste, and in poorly ventilated confined spaces, such as manure tanks including those that are uncovered. The hazards to both humans and animals include death, incapacitation, impairment of the ability to self rescue, or acute illness. A hazardous atmosphere occurs when flammable gases and vapors reach their flammable limit, when oxygen concentration is below 19.5 percent or above 23.5 percent, and when concentration of toxic gases exceeds permissible exposure limits. The AWMS plan should address these hazards and how to appropriately remediate or improve them. It is important that others, such as family members, who may frequent an AWMS be aware of the hazards of these situations as well.

Ventilation breakdowns—Ventilation depends on properly operating fans or vents. With no natural drafts to replenish the air in confined areas, death by asphyxiation from lack of oxygen and increased carbon dioxide, by poisoning from other gases, or by some combination of these can occur. Operators must be alert to failure of ventilation systems and take immediate action to either repair the system or activate a backup system until repairs can be made. Operators must also be aware of the dire consequences of purposely blocking ventilation systems, which may be considered during cold weather to reduce heat loss.

Agitation—Agitation of wastes to facilitate transfer and other waste management functions is a common practice in an AWMS. This activity may release large quantities of noxious gases and create dangerous and possible lethal conditions even with maximum ventilations. If agitation is done outdoors, it seldom is a problem; however, lethal conditions are a potential when it is done within buildings. To minimize the hazards, agitation should be done on mild days so the building can be ventilated to full capacity. For naturally ventilated buildings, it is best done on windy days. Animals should be removed from the building before the agitation is started, but if they are not removed, they should be observed for signs of ill effects.

Confined space—Death resulting from persons entering a covered waste storage tank or other confined space in an AWMS occurs all too often in the United States. Multiple deaths frequently occur when the first person to enter the confined space and the would-be rescuers all succumb to the atmosphere of the facility. These are tragic occurrences, and every safety precaution should be used to prevent them.

Often a person enters a tank as a spur-of-the-moment reaction to the desperate need for assistance to an animal or person who has accidentally fallen into the facility. Steps can be taken to avoid this type of accident. First, the AWMS design should include, and its plan should indicate, maintenance of such devices as grates and covers that prevent accidental entry from happening. Design consideration should also be given to:

- Features that minimize the need for confined space entry.
- Provisions that allow for maintenance of equipment outside the space or for equipment parts that can be easily retracted for maintenance.
- Corrosion resistant equipment that performs with minimum maintenance in caustic environments.
- Power ventilation systems that provide for both a supply of fresh air and exhaust of accumulated gases.

Secondly, the people who operate or frequent an AWMS must be made aware of the absolute rule that no one enters these facilities under any circumstance unless preparations have been made for their safe entry. Signs (fig. 13–5) should be prominently posted and maintained that warn of the hazard. Children and those that cannot read must be given special instruction to assure that they are aware of the hazard.

Entry into a confined space is sometimes necessary. Examples include:

- To inspect a tank for cracks and leaks.
- To rescue someone or something.

Confined spaces should, however, only be entered after preparations have been made for a safe entry. For this reason, the AWMS plan needs to address safe entry into confined spaces.

Some States may regulate entry into confined spaces for agricultural operations. The appropriate occupational and safety agency should be contacted to determine what the requirements are. The U.S. Department of Labor, Occupational Safety and Health Administration, has rules and regulations on entering confined spaces (Federal Register 1993). The regulatory aspects of these rules do not apply to agriculture. However, from a safety standpoint these rules should be followed to ensure the safety of persons required to enter hazardous confined spaces. Following is a summary of the practical aspects of these rules as they apply to entry of AWMS confined spaces:

- Any condition making it unsafe to remove an entrance cover to a confined space shall be eliminated before the cover is removed.
- When entrance covers are removed, the opening shall be promptly guarded by a railing, temporary cover, or other temporary barrier that will prevent an accidental fall through the opening and will protect persons working in the space from objects entering the space.
- Before a person enters the space, the internal atmosphere shall be tested with a calibrated direct-reading instrument for the following conditions in the order given:
  1. Oxygen content
  2. Flammable gases and vapors
  3. Potential toxic air contaminants

Figure 13–5 Confined space warning signs

- No hazardous atmosphere can be within the space whenever any person is inside the space.
- Continuous forced air ventilation shall be used as follows:
  - † A person may not enter the space until the forced air ventilation has eliminated any hazardous atmosphere.
  - † The forced air ventilation shall be so directed as to ventilate the immediate areas where a person is or will be present within the space and shall continue until all persons have left the space.
  - † The air supply for the forced air ventilation shall be from a clean source and may not increase the hazards in the space.
- No one should enter a confined space without a qualified safety watcher stationed outside the space. Persons entering confined space should know the hazards that may be faced during entry, be equipped with a full body harness with a retrieval line attached to a mechanical rescue device, and be able to communicate with a safety watcher. The safety watcher must be able to communicate with those inside the space and be able to perform the actions required to retrieve those inside the space.
- The atmosphere within the space shall be periodically tested as necessary to ensure that the continuous forced air ventilation is preventing accumulation of a hazardous atmosphere.
- If a hazardous atmosphere is detected during entry:
  - † Each person shall leave the space immediately.
  - † The space shall be evaluated to determine how the hazardous atmosphere developed.
  - † Measures shall be implemented to protect persons from the hazardous atmosphere before any subsequent entry takes place.

To fully implement the above procedure, the AWMS plan should recommend employing a safety professional who has the training and the testing equipment necessary to ensure a safe confined space entry. Local or State Government safety agencies may provide this service upon request. Some States require insurance companies that supply coverage for occupational accidents to provide their clients with consultation services on safety related problems.

A well thought-out plan of action for dealing with emergencies involving accidental entry into confined spaces needs to be included in the AWMS plan. The plan should recommend that the decisionmaker educate all who are involved in the operation of an AWMS in carrying out the plan. An AWMS plan should:

- Include a rescue service that could be called for assistance in an emergency.
- Suggest that equipment needed for emergency rescue, such as self contained breathing apparatus, life lines, and harnesses, be close at hand.
- Address the specific hazards from gases in each of the applicable functions of the AWMS.

Safety equipment used in confined space is described in chapter 12.

(b) Hazards with impoundments

Impoundment type components, such as waste storage ponds, waste treatment lagoons, and waste storage tanks, present a drowning hazard. The hazard for earthen waste impoundments is similar to that associated with any farm pond. However, crusts that may form on the water surface and slime formation make waste impoundments more hazardous.

Crusts have the appearance that they would support a person's weight; however, they often will not. The consequence of falling through the crust on a waste impoundment would be similar to falling through the ice on a pond—there is no escape. Slime that forms on the surface of impoundments makes them very slippery, and as such makes it easy for a person to loose their footing on inclines. In cold climates, ice formation can make any surface unsafe. Geotextile liners are generally smooth, and when wet they are so slippery a foothold cannot be achieved.

The best approach to minimizing the hazards of drowning in waste impoundments is to include features in the design to exclude both animals and people (fig. 13–6). This can be accomplished with fences and warning signs. Gates should be locked to limit access except to those who need to enter the impoundment area. Provision needs to be provided for emergency exit in case someone accidentally enters these areas. Prominent signs indicating the hazard should be displayed. The AWMS plan needs to emphasize the importance of maintaining these safety features.

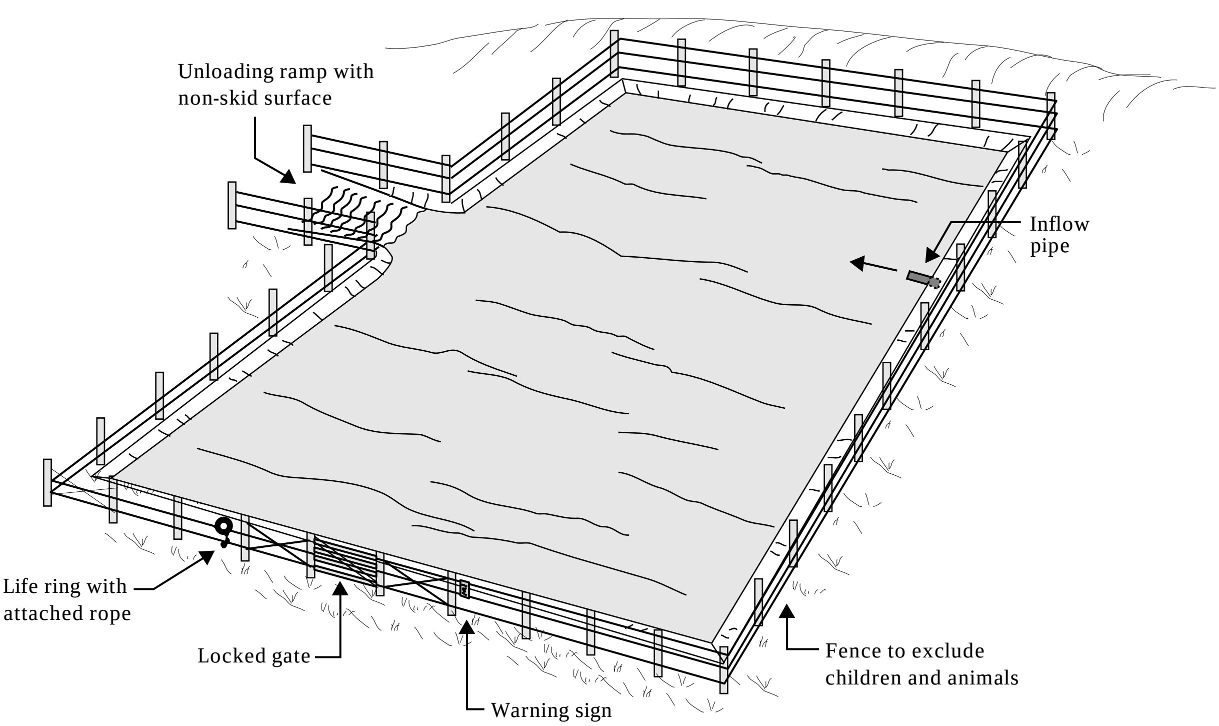
On some occasions, personnel must operate near these impoundments. The AWMS plan should recommend that life rings, life lines, poles, and boats be close at hand to assist in making a rescue.

Design of push-off ramps should include:

- Sturdy guard rails to prevent people and equipment from falling into waste impoundments.
- Loading ramps with a traction surface to minimize slipping.
- Walkways constructed of nonslip surfaces.

People can do little to escape if they fall into a storage tank with vertical walls. The side of the tank is slick and has nothing to hang onto unless it is provided. For this reason tank access should be limited to those who have need for entry. A ladder on the outside of the tank should terminate above the reach of people or should have locked entry guards.

Figure 13–6 Waste storage pond safety features



Some tanks have platforms for such equipment as solid/liquid separators and pumps. The platform should be equipped with guard rails to prevent accidental falls into the tank. A rope dangling from the platform would allow improved opportunity for survival from an accidental fall from the platform into the tank.

Providing a means of survival from accidental entry should also be considered for below-ground tanks; however, whatever is done should never invite entry. Examples of things to consider include:
- A ladder hinged to the tank cover that can be pulled down with a rope to allow escape.
- Perches installed on the tank floor or wall that a person can stand on to attain fresh air and call for help.

The AWMS plan should discuss the specific hazards of impoundments in each applicable function. Generally, this hazard would be discussed in an AWMS plan for systems that have waste storage ponds or tanks in the storage function and for systems that have waste treatment lagoons in the treatment function. See chapter 12, section 651.1204, for additional information on safety equipment for impoundments.

(c) Hazards in equipment operation

Equipment used in an AWMS is varied. Chapter 12, Waste Management Equipment, describes equipment used in an AWMS, as well as safety aspects of equipment operation. A few guiding principles in the safe operation of equipment should be included in the AWMS plan. Safety procedures should also be included. The procedures could include:
- Assuring that moving parts that would expose an operator to injury are properly guarded.
- Providing and using backup signals on equipment as appropriate.
- Maintaining electrical equipment and assuring that it is properly grounded.

Perhaps the most important safety precaution is assuring the equipment operators are trained in the safe use of the equipment before being allowed to operate it. This should be recommended in the AWMS plan. It is equally important that operators only be allowed to use equipment when they are well rested and not under the influence of a drug, prescribed or otherwise, which would impair their ability to operate the equipment safely.

The decisionmaker should be advised in the AWMS plan of the necessity of requiring workers to use personal protective equipment when appropriate (fig. 13–7). Rollover protective structures and seat belts should be on all equipment that is ridden. Safety belts should be used if there is a potential of falling.

Because many surfaces in an AWMS are slippery, shoes or boots with soles having good traction should be used. Hearing protection should be used if the noise level and duration would contribute to hearing loss. Operators should use eye and face protection if machines or operations present potential eye or face injury. Work areas should be well ventilated. If they are not, workers should use appropriate respiratory protection. Proper lighting is also important in providing a safe work environment.

The AWMS plan should discuss the specific hazards of the equipment used in each function of the AWMS.

Figure 13–7 Personal safety equipment

651.1304 Agricultural waste management system plans

The purpose of an AWMS plan is to convey to the decisionmaker details of the construction and O&M requirements of the system. It is important to remember this in its preparation. As such, the plan should have an easily followed format, use familiar terms, and be concise. It should be neat, invite reading, and be worthy of retention. Presenting the plan to the decisionmaker in a 3-ring binder encourages retention. An electronic copy could be provided those decisionmakers having computers. See Chapter 2, Planning Considerations, and Chapter 9, Agricultural Waste Management Systems, for more information on the AWMS plan.

The preparation of the AWMS plan requires input from all disciplines involved in the planning and design of the system. Information from the AWMS's planning documentation must be extracted for inclusion in the plan. This would include information extracted from inventories, investigation reports, alternatives considered, design reports, installation schedules, and other information that is necessary for explaining the system requirements. However, it is generally not appropriate to include the planning and design documents in their entirety.

An AWMS component design report should be reviewed to ascertain O&M activities that may have been identified as necessary for the component's performance. These O&M activities should be included in the O&M plan. The plan should include maps, charts, and other illustrative aids that enhance understanding of the system's O&M requirements. Appendix C is an example AWMS plan for a simple agricultural waste management system. A suggested format follows.

Name, address, and location of AWMS—This is self-explanatory.

General statement—Should indicate the purpose of the AWMS and the importance of O&M.

General description of AWMS—Should include the type and size of operation and the basic components of the AWMS. Including a plan view drawing of the component layout would be helpful for describing the AWMS.

Decisionmaker's responsibilities—It is suggested that this section clearly state that proper and safe system operation and maintenance within the laws and regulations are the responsibility of the decisionmaker.

Component installation schedule—Should consider proper sequence of installation so that each component will function as intended in the system.

Operation and Maintenance of production, collection, storage, treatment, transfer, and utilization functions— The specific O&M requirements for each function of the AWMS should follow the component installation schedule section. These requirements should expand on the general O&M considerations described in this chapter and include the appropriate safety requirements.

Decisionmaker's acknowledgment—This last section is intended to include a signature line allowing the decisionmaker to attest to having read and understood the plan.

651.1305 References

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